LS-163
March, 1991

The APS Transfer Line from Linac to Injector Synchrotron.

R. K. Koul and E. Crosbie
Argonne National Laboratory

This note describes the low-energy-transfer-line designed for the APS. The low energy transfer line constitutes two transport lines. One of these lines runs from linac to the positron accumulator ring ,also called "PAR", and is 23.7138 m long. The second part of the low energy transport line runs from the "PAR" to the injector synchrotron and is about 30.919 m long. The above length includes two quadrupoles, a bend magnet and a septum magnet in the injector synchrotron (see fig. 1 and table 2).

The positron bunches of emittance $\epsilon_N = 1.1 mm - mrad$ arriving at the end of the linac at 450 MeV have twiss parameters as given by Nassiri[1]

$$\alpha_x = 1.6808, \beta_x = 7.2161, \alpha_y = -1.7586, \beta_y = 6.6888$$

.

The transfer line (see also Yoon and Crosbie[2]) from linac to "PAR" is made up of ten quadrupoles and one bending magnet B4 (see fig.1). The bending magnet bends the beam by 0.2 radians towards the septum magnet in the "PAR". The five quadrupoles in the region between the bend magnet and the septum magnet in the "PAR" give a phase shift of 2π radians, in order to get dispersion free bunch at the end of the septum magnet. The twiss parameters at the end of the linac given above are matched with the twiss parameters and the dispersion functions at the end of the septum magnet, in the "PAR" lattice structure. These parameters at the end of the "PAR" septum are given by

$$\alpha_x = -0.94910, \beta_x = 2.1261, \alpha_y = -0.02429, \beta_y = 8.2401, \eta_x = 0.0, \eta'_x = 0.0$$

.

The matching procedure was carried out using computer code "COMFORT". It should be mentioned that the 2.9 m of distance between the last quadrupole and the septum magnet in the "PAR" is more or less forced on us because of the considerations of the available space in that region. The layout of this region of the transfer line is shown in fig. 1. Details of the magnet dimensions and their strengths are given in table 1. The order of the magnets is the order in which they appear in the transfer line as one traverses from the linac to "PAR". The β functions in the horizontal and the vertical plane along with the dispersion function, η, in the horizontal plane are shown in the fig. 2. The maximum β_y is approximately 20 m and occurs at the quadrupole before the bend magnet. The maximum value of the β_x is about 16 m.

In addition to the above elements, the linac to "PAR" part of the low energy transfer line contains eight steering magnets and seven beam position monitors. Of the eight steering magnets four are for steering in the horizontal plane and the remaining four are to be used for steering in the vertical plane. Similarly, out of the seven beam position monitors three are to be used for diagnostics in the horizontal plane and the remaining four for diagnostics in the vertical plane. The relative positions of these steering magnets are also given in fig. 1. The calculations for the strength and the dimension of these steering magnets was carried out using a computer code locally developed for this purpose. However the code was tested for the calculation of twiss parameters against the "COMFORT" run. Two sample plots for the particle trajectory along the horizantle direction for a given kick, obtained by the above computer code are given in the fig. 4 and fig. 5 .

The second part of the low energy transport line carries the positron bunches from the "PAR" septum to the injector synchrotron. Again the energy of the positron bunches is about 450 MeV. This section is made up of two bend magnets (B1 , B2), and eleven quadrupoles joining the "PAR" septum magnet "B3" on the one end and the injector synchrotron septum magnet on the other end. The bend magnet B2 bends the bunch, coming from the "PAR" septum magnet (bend angle of -0.2 radians) through an angle of 0.2 radians. The section between the bend magnet B2 and the septum magnet B3 is the same as the section between the bend magnet B4 and the septum magnet B3. It produces dispersion free beam in the region between B2 and B1 . The next section between bending magnet B2 and the bending magnet B1 has four quadrupoles which can be used as tuning quadrupoles for tuning on to four twiss parameters in the vertical and horizontal direction. The bend magnet B1 bends the beam at an angle of -0.1859 radians approximately towards the injector synchrotron septum. There are two quadrupoles in the section between the bend magnet B1 and the injector synchrotron septum, which are arranged such that the bunches entering the injector synchrotron are dispersion free at the end of the dipole magnet B (see Table 2). The detailed layout can be seen in fig. 1, and the relative positions the dimensions and the strengths of the magnets are given in table 2. The maximum value of the β function from B2 to the injector synchrotron septum is about 26 m. In designing the transfer line from the "PAR" to the injector synchrotron, some part of the injector synchrotron is included. The twiss parameters given by the injector synchrotron lattice at the beginning of the drift O1 (see Table 2.) are matched with the twiss parameters given at the beginning of the "PAR" septum magnet given above (sign of the α function must be reversed), through the transfer line. Again, the computer code "COMFORT" was used for matching purposes. The twiss parameters at the position O1 are given bellow. The sign of the α function corresponds to the motion from "PAR" to the injector synchrotron.

$$\alpha_x = 0.4620, \beta_x = 2.1724, \alpha_y = -2.5084, \beta_y = 15.6557$$

The detailed form of the β_x , β_y and the η_x is given in the fig. 3 . In addition to the above components this part of the transfer line contains six steering magnets and seven beam position monitors. Out of the six steering magnets, three are used for steering in the horizontal direction and the remaining three in the vertical direction. Similarly, of the seven beam position monitors four are to be used for monitoring the horizontal position and the remaining three for monitoring the vertical position. The maximum $B\ell = 0.012$ T.m for these steering magnets. These calculations were carried out using, as mentioned above, a locally developed code. The details of their positions and other parameters are given in the table 2. .

1. References

1. Alli Nassiri, Private communication.
2. M. Yoon and E. Crosbie, APS note LS-119 (1988).

Table 1: LTOP PARAMETERS
(450 MeV. Bρ = 1.503 T-meter. -Positive K_1 means horizontal defocussing.)
Input Twiss Parameters:$\alpha_x = 1.6808, \beta_x = 7.2161, \alpha_y = -1.7586, \beta_y = 6.6888$
Output Twiss Parameters:$\alpha_x = -0.0949, \beta_x = 2.1261, \alpha_y = -0.0243, \beta_y = 8.2401$

Element	Length	θ or Magnet Strength $K_1 = B'/B\rho[m]^{-2}, \rho[m]$	Theta1	Theta2
DRIFT:O1	1.84			
$Steering_y$	0.05	0.18		
DRIFT:O1	0.1			
QUAD:Q1	0.3	1.32161191		
DRIFT:O2	2.36			
QUAD:Q2	0.3	-0.791489118		
DRIFT:O3	0.1			
$Steering_x$	0.05	0.18		
DRIFT:O3	2.65			
QUAD:Q3	0.3	-1.22476908		
DRIFT:O4	2.04			
BPM_y				
DRIFT:O4	0.1			
QUAD:Q4	0.3	2.22022831		
DRIFT:O5	0.1			
$Steering_y$	0.05	0.18		
DRIFT:O5	1.78697			
BPM_x				
DRIFT:O5	0.1			
QUAD:Q5	0.3	-2.90560407		
DRIFT:O6	0.1			
$Steering_x$	0.05	0.18		
DRIFT:O6	0.63			
SBEND:B2	0.4	0.2	0.1	0.1
DRIFT:O7	0.80			
BPM_y				
DRIFT:O7	0.1			
QUAD:Q14	0.3	4.13661613		
DRIFT:O9	0.1			
$Steering_y$	0.05	0.18		
DRIFT:O9	0.75			
BPM_x				
DRIFT:O9	0.1			
QUAD:Q15	0.3	-4.87910321		
DRIFT:O9	0.1			
$Steering_x$	0.05	0.18		
DRIFT:O9	0.75			
BPM_y				
DRIFT:O9	0.1			
QUAD:Q16	0.3	4.2311		
DRIFT:O9	0.1			
$Steering_y$	0.05	0.18		
DRIFT:O9	0.75			
BPM_x				
DRIFT:O9	0.1			
QUAD:Q17	0.3	-3.64756051		
DRIFT:O9	0.1			
$Steering_x$	0.05	0.18		
DRIFT:O9	0.85			
QUAD:Q18	0.3	0.518257169		
DRIFT:O8	0.3			
BPM_y				
DRIFT:O8	2.606796672			
SBEND:B3	0.4	-0.2	-0.0	-0.2

Table 2: PTOB PARAMETERS
(450 MeV. $B\rho = 1.503$ T-meter, -Positive K_1 means horizontal defocussing.)
Input Twiss Parameters:$\alpha_x = 1.6808, \beta_x = 7.2161, \alpha_y = -1.7386, \beta_y = 6.6888$
Output Twiss Parameters:$\alpha_x = -0.0949, \beta_x = 2.1261, \alpha_y = -0.0243, \beta_y = 8.2401$

Element	Length	θ or Magnet Strength $K_1 = B\prime/B\rho[m]^{-2}, \rho[m]$	Theta1	Theta2
$SBEND$:B3	0.4	-0.2	0.0	-0.2
$DRIFT$:O14	2.906796672			
QUAD:Q13	0.3	0.518257169		
$DRIFT$:O13	0.9			
BPM_x				
$DRIFT$:O13	0.1			
QUAD:Q12	0.3	-3.64756051		
$DRIFT$:O12	0.1			
$Steering_x$	0.05	0.21		
$DRIFT$:O12	0.75			
BPM_y				
$DRIFT$:O12	0.1			
QUAD:Q11	0.3	40.2341		
$DRIFT$:O11	0.1			
$Steering_y$	0.05	0.07		
$DRIFT$:O11	0.75			
BPM_x				
$DRIFT$:O11	0.1			
QUAD:Q10	0.3	-4.87910321		
$DRIFT$:O10	0.1			
$Steering_x$	0.05	0.153		
$DRIFT$:O10	0.75			
BPM_y				
$DRIFT$:O10	0.1			
QUAD:Q9	0.3	4.13661613		
$DRIFT$:O9	0.1			
$Steering_y$	0.05	0.15		
$DRIFT$:O9	0.75			
$SBEND$:B2	0.4	0.2	0.1	0.1
$DRIFT$:8E	0.50			
BPM_x				
$DRIFT$:8E	0.1			
QUAD:Q8	0.3	-2.52401148		
$DRIFT$:8D	0.60			
QUAD:Q7	0.3	2.53513652		
$DRIFT$:8C	0.87279645			
$Steering_x$	0.05	0.18		
$DRIFT$:8c	0.1			
QUAD:Q6	0.3	-2.51912868		
$DRIFT$:8B	0.5			
BPM_y				
$DRIFT$:8B	0.10			
QUAD:Q5	0.3	2.74505552		
$DRIFT$:8A	0.1			
$Steering_y$	0.05	0.13		
$DRIFT$:8A	0.45			
$SBEND$:B1	0.4	-0.18586022	-.09293011	-.09293011
$DRIFT$:O7	1.739450476			
BPM_x				
$DRIFT$:O7	0.1			
QUAD:Q4	0.30	-1.52786061		
$DRIFT$:O6	0.9			
QUAD:Q3	0.30	0.82701161		
$DRIFT$:O5	0.9			
	(Inside Booster)	(Inside Booster)		
$SBEND$:SEP	0.8	0.26754	0.13377	0.13377
$DRIFT$:O4	1.55			
QUAD:Q2	0.50	0.638272		
$DRIFT$:O3	0.5115			
$SBEND$:B	3.077	-0.09239978	0.04619989	0.04619989
$DRIFT$:O2	0.5115			
QUAD:Q1	0.50	-0.710565		
$DRIFT$:O1	4.1			

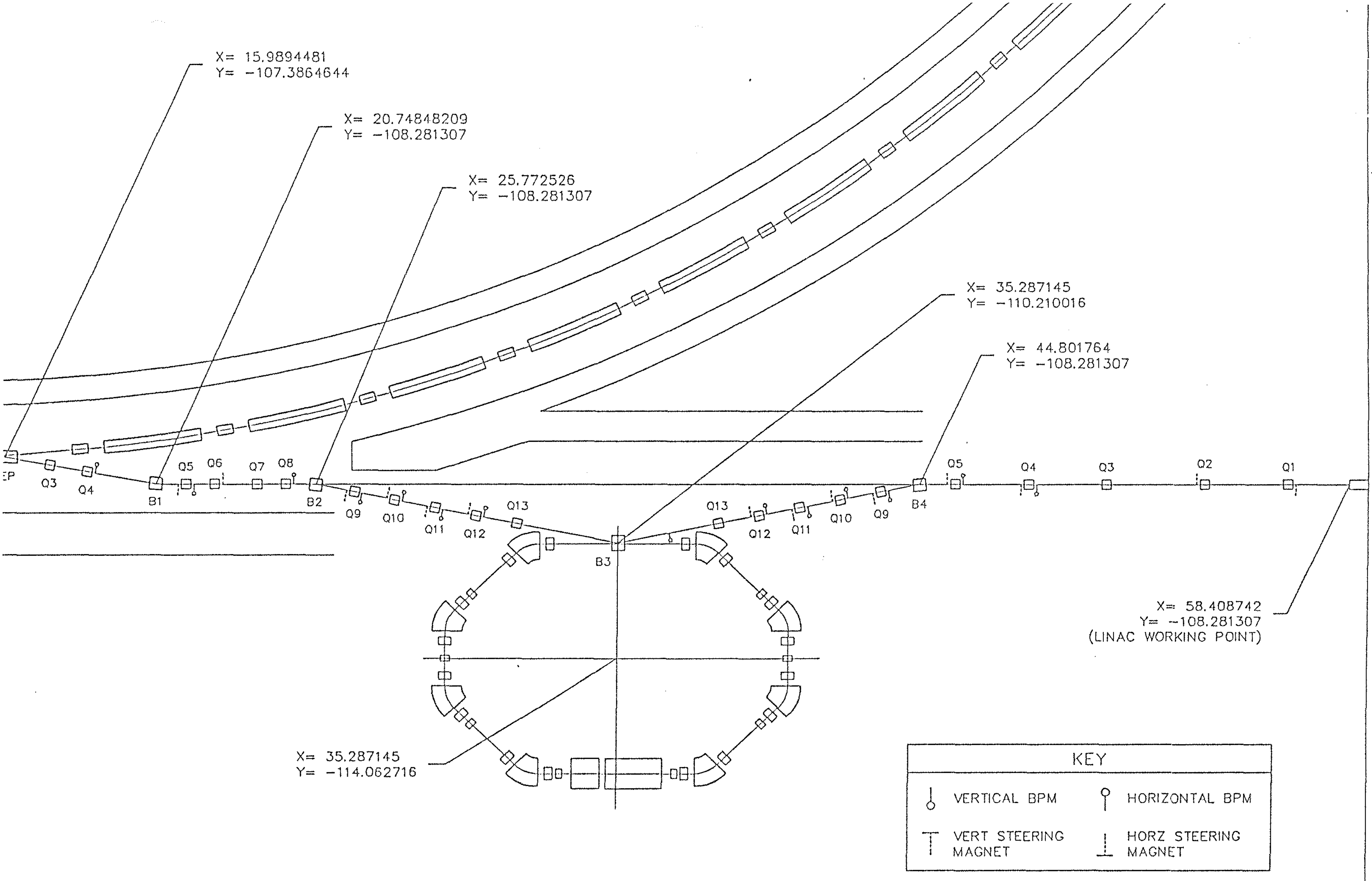
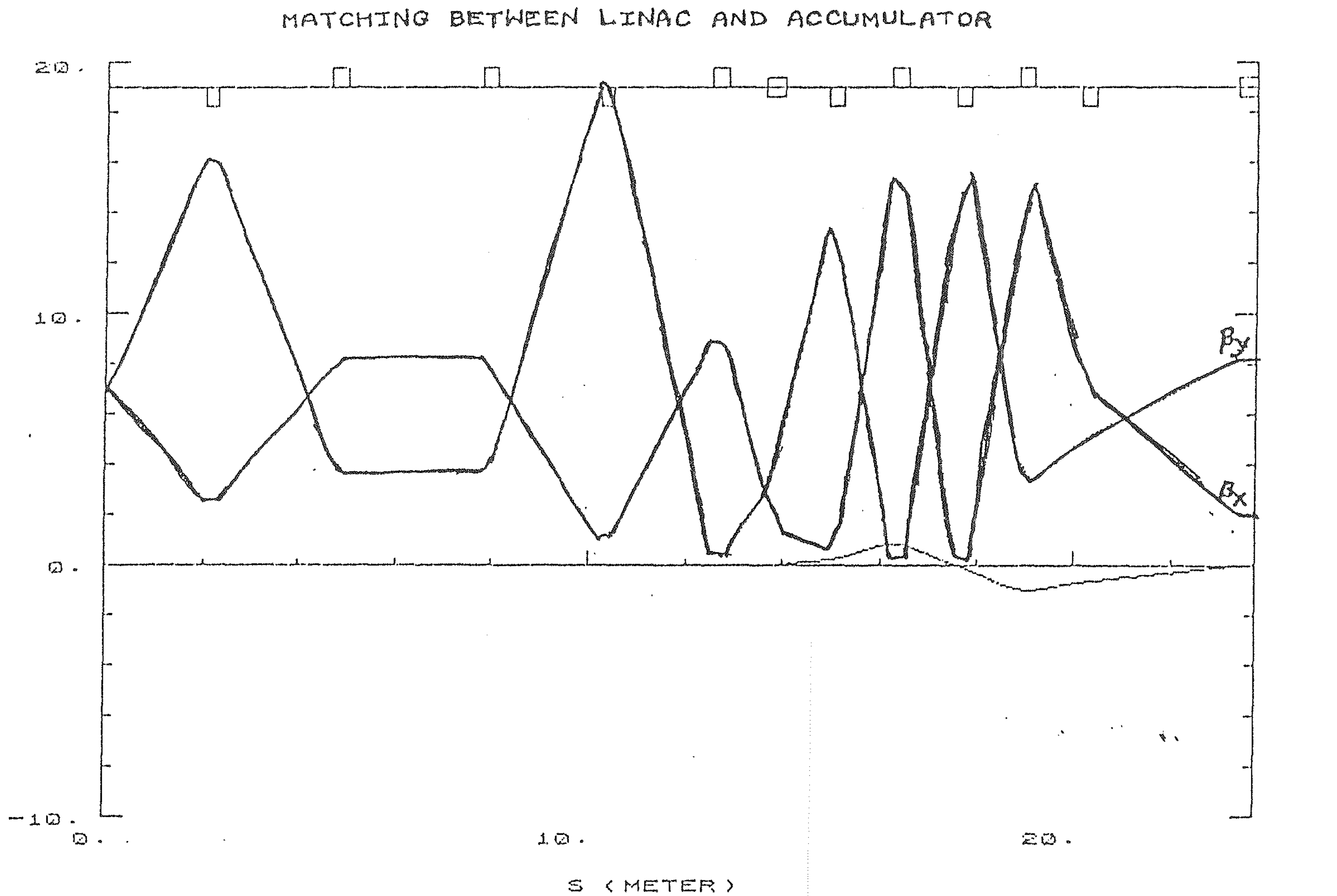


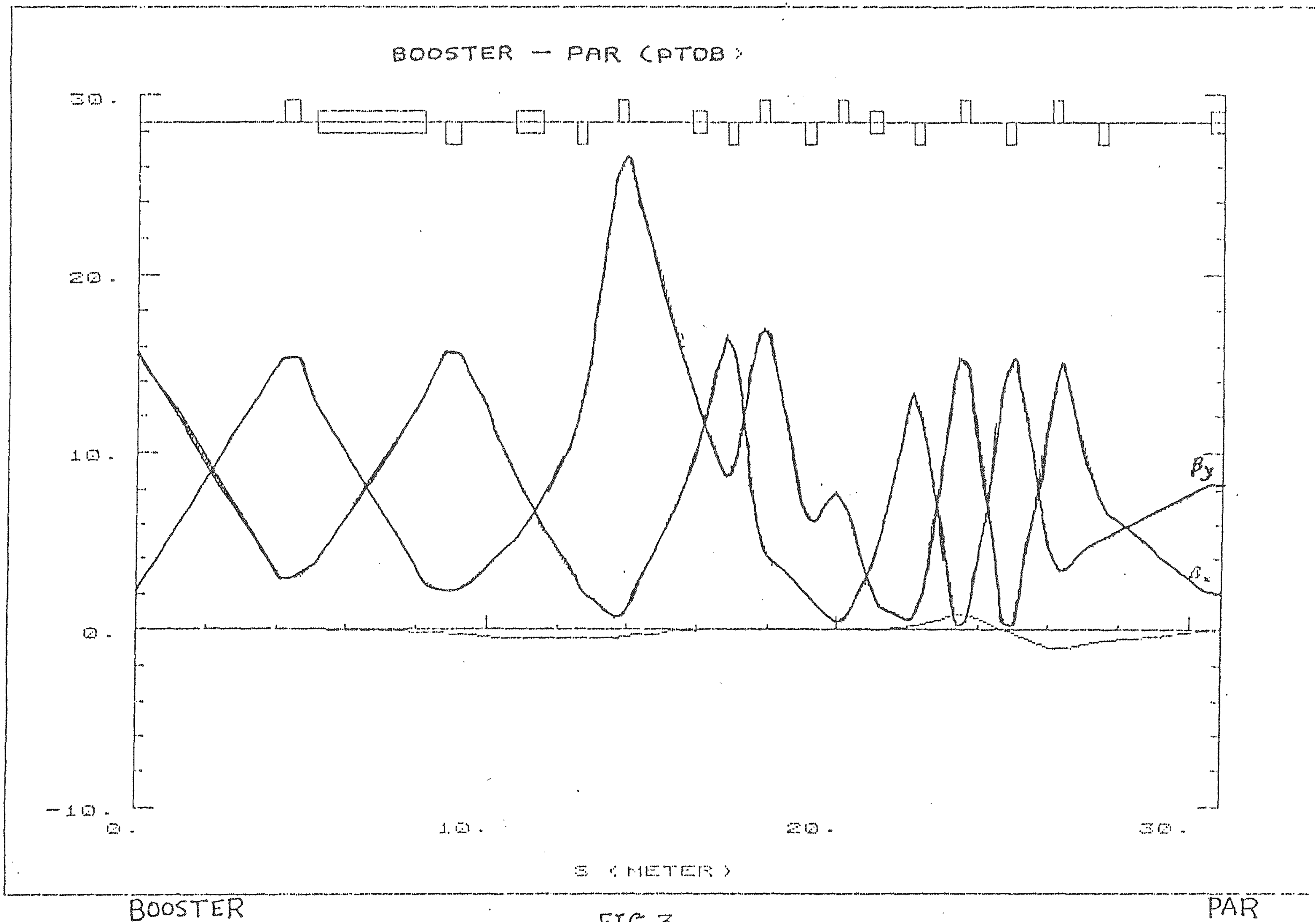
FIGURE 1. LOW ENERGY TRANSPORT LINE

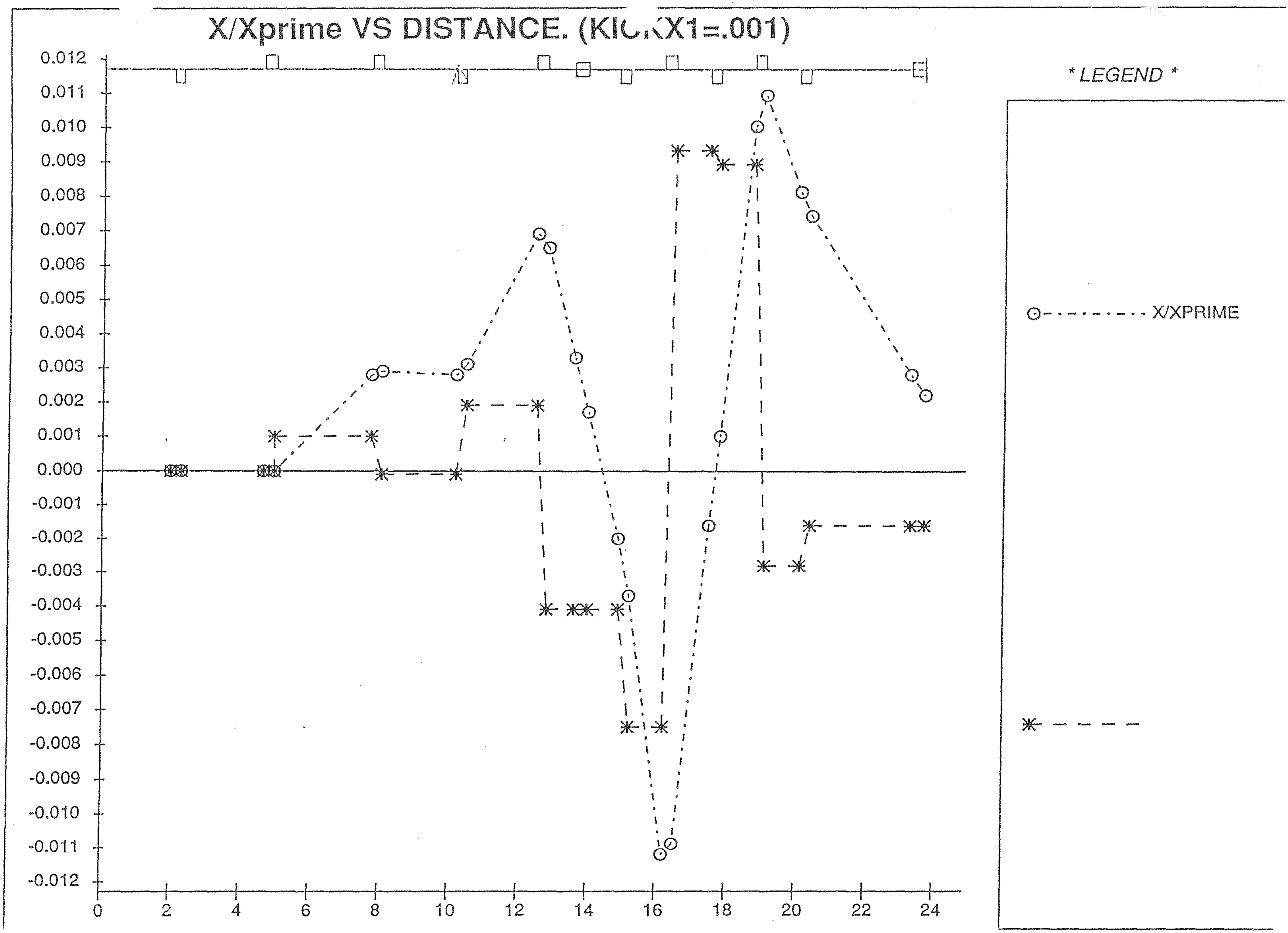
FIG

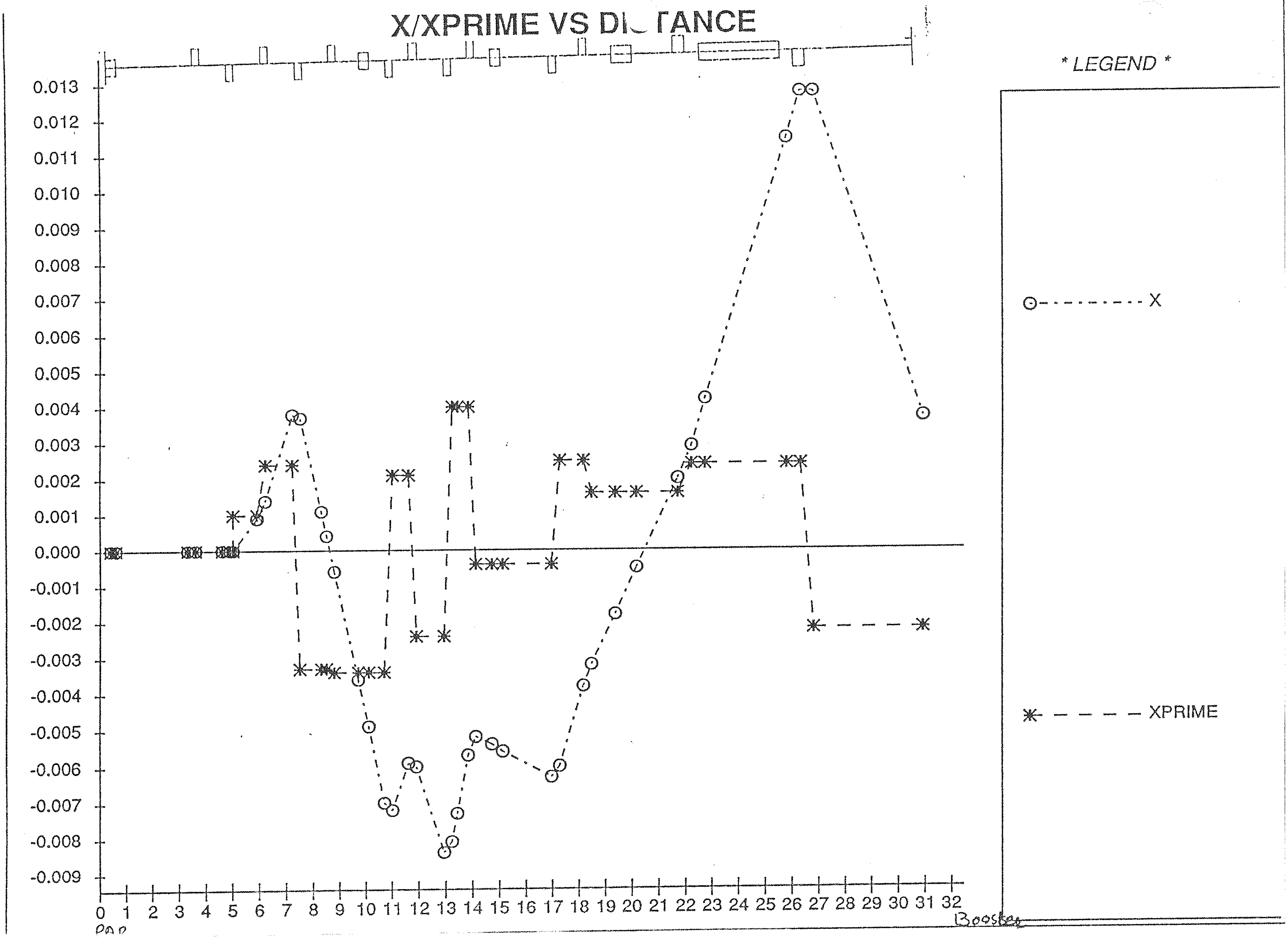


LINAC PAR

FIG. 2


BOOSTER — PAR (PTOB)
30.
20.
10.
0.
-10.
0.
10.
20.
30.
S (METER)
β_y
β_x
BOOSTER
PAR
FIG. 3


X/Xprime VS DISTANCE. (KICKX1=.001)
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
-0.008
-0.009
-0.010
-0.011
-0.012
0
2
4
6
8
10
12
14
16
18
20
22
24
* LEGEND *
X/XPRIME


X/XPRIME VS DI TANCE
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
-0.008
-0.009
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
Booster
* LEGEND *
X
XPRIME